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INSTITUTE FOR DEFENSE ANALYSES

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Daniel B. Levine, Project Leader
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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Assistant Secretary of Defense (Economic Security) under a task entitled "Preplanned Product Improvements and Engineering Change Proposals for Consolidated Automated Support Systems (CASS)." The publication responds directly to a sponsor request.

This work was reviewed within IDA by Bruce N. Angier and George C. Tolis.

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TABLES

A. INTRODUCTION

This report documents research that the Institute for Defense Analyses (IDA) carried out on the Electro-Optic Subsystem (EOSS+), the electro-optical module being developed for the Consolidated Automated Support System (CASS). The research was sponsored by the Director, Weapon Support Improvement Group, Office of the Assistant Secretary of Defense (Economic Security) and conducted for the CASS Program Office, PMA-260 in the Naval Air Systems Command. We presented the results of this research in a briefing to PMA-260 in April 1996, when production of the EOSS+ was a current issue. Our findings were generally favorable to the EOSS+, and the Program Office has since embarked on a program to procure eight of the systems. Because a year has elapsed between our work and this documentation, some of the information in this report might be out of date.

The CASS Program Office asked IDA to perform three tasks: (1) compare the costs and effectiveness of the EOSS+ and EOSS, the earlier version of the EOSS+; (2) determine the number of tri-Service electro-optical systems the EOSS+ could test; and (3) identify any technical risks to the EOSS+ program. Succeeding sections take up these topics in turn. To complete these tasks, we held discussions in early 1996 with Northrop's CASS development team, and obtained data from Northrop [1], the Avionics Installation Plan published by the Naval Avionics Center in August 1991 [2], the Jacksonville Naval Depot [3], the U.S. Army Missile Command at Redstone Arsenal [4], and a previous IDA report [5].

B. BACKGROUND

The EOSS+ is being developed by Northrop Grumman under contract to Lockheed Martin, the prime CASS contractor. It is being developed to lower the cost and correct some technical problems of an earlier version of the CASS Electro-Optical module, the EOSS. For example, the EOSS had a large rotating mirror which made performing good tests in the presence of vibration difficult. For the EOSS+, Northrop re-designed the optical system to eliminate the mirror.

Other improvements include replacing the forced-air cooling system with a less-costly ambient air system; installing Built-In-Test (BIT) and self-test fault isolation systems, which should lower the mean time to repair; and increasing the mean time between failure from 4,610 hours to an estimated 6,000 hours to improve reliability and reduce the costs of spares.

C. COST EFFECTIVENESS

Our analysis finds that the EOSS+ is clearly superior to the EOSS: it is both less costly and more capable. Table 1 shows that although the EOSS+ would cost slightly more than the EOSS to complete development, its unit procurement and support costs are much lower, so that its 10-year program cost is almost 40% less. The 10-year costs are particularly sensitive to the annual Operations and Maintenance (O&M) cost per console: the total 10-year O&M costs for all 38 units discounted by 3.5% annually are approximately 65% of the total 10-year costs of both alternatives. [The Office of Management and Budget (OMB) mandates a 3.5% annual discount rate for 10-year analyses.] These O&M costs might be much lower than those shown in Table 1 if the consoles were supported by the Navy instead of through a support contract with Lockheed Martin (see note d to the table). The O&M costs of both systems would likely fall in parallel, however, still leaving the EOSS+ less costly. Even if these O&M costs fell by 50%, for example, the EOSS+ would still cost approximately 40% less than the EOSS.

Table 1. Cost of EOSS vs. EOSS+

	Cost in Millions of FY 1995 Dollars	
	EOSS	EOSS+
Development remaining	$2.6	$4.9
Unit procurement[a]	3.8	2.1
Support		
1 set of spares[b] for interim support	3.4	1.2
Initial provisioning per console[c]	0.68	0.38
Annual O&M per console[d]	0.98	0.64
10-year program cost, discounted at 3.5% annually, for buy of 38 units[e]	$486.0	$302.6

[a] Based on Lockheed Martin estimate for a buy of nine.
[b] Prior to government acceptance.
[c] 18% of unit procurement, a factor used by the CASS Program Office.
[d] 20% of unit procurement cost of the EO console plus a CASS hybrid ($1.1 million); this is an approximate charge for an 80% availability support contract.
[e] The number of EO stations being planned by PMA-260.

The EOSS+ is thus less costly than the EOSS. Our detailed comparison of the two systems shows that it is also more effective. Table 2 shows that the EOSS+ performs equal to or better than the EOSS in terms of both general features and specific test areas. Table 3 is a summary of a detailed analysis of the 7 test areas representing over 30 tests.

Table 2. Areas of EOSS+ Superiority vs. EOSS

General features
Reduced alignment requirements between unit under test (UUT) and tester
Improved diagnostics
Higher number, range, and accuracy of test targets
Improved measurement accuracy under vibration
Increased boresight accuracy
Minimum Resolvable Contrast TV functionality
Lower cooling cost: ambient cooling vs. external supply of forced air for the EOSS
Shorter run time
Higher predicted reliability: mean time between failure of 6,000 hours for the EOSS+ vs. 4,610 hours for the EOSS
Test areas
Alignment accuracy
IR sensor
Laser transmitter
Laser receiver
Laser spot tracker
TV sensor
Multi-sensor boresight

Table 3. Specific Test Comparison between EOSS and EOSS+

Alignment accuracy	EOSS+ is better
IR sensor (11 tests)	Equal capability
Laser transmitter	
Beam divergence and alignment	EOSS+ is better
Other laser transmitter tests (4 tests)	Equal capability
Laser receiver	
Sensitivity, automatic gain control, time program gain, source minimum power	EOSS+ is better
Source maximum power	EOSS+ has lower power, but higher power is not needed and also decreases reliability
Laser spot tracker position range	
Static	EOSS+ is better
Dynamic	EOSS+ has lower range but higher accuracy
TV sensor	
Gain radiance measurement	EOSS+ has a lower maximum, but higher performance in this area is unneeded and also decreases reliability
Field of view, minimum resolvable contrast	EOSS+ is better (EOSS lacks capability)
Other TV sensor tests (5 tests)	Equal capability
Multi-sensor boresight alignment	
Laser-FLIR, laser-TV	EOSS+ is better

The results show that the EOSS+ is as good or better than the EOSS in almost all tests, and falls behind the EOSS only in cases where the higher capability of the EOSS offers no operational advantage. The EOSS+ is thus superior to the EOSS in both cost and effectiveness.

D. COVERAGE

This section presents a separate discussion of the ability of EOSS+ to test the electro-optical (EO) systems of the Navy and Marine Corps and of the Army.

1. Navy and Marine Corps Systems

Table 4 describes the testability of 31 EO systems found on 21 Navy and Marine Corps aircraft, including all 13 electro-optical systems installed in the F-14D, AV-8B, and F/A-18 A/B/C/D (1970-80 technology), and the F/A-18 E/F (1990 technology). The only exception is the AV-8B's night goggle set, the MXU-81(U), which is not designed for automatic testing. The systems described by the first three columns were obtained from the Avionics Installation Plan [2]. The number of aircraft on which these systems were found (and thus the number of systems themselves on Navy and Marine Corps aircraft) are old data, and thus of only general usefulness. The Jacksonville Naval Depot provided the testability information shown in columns 5-6 [3].

Table 5 is a summary of the testability of the 31 systems shown in Table 4. Table 5 shows that EOSS+ would not likely be considered for 16 of the systems for a variety of reasons, *none of which is a known technical shortcoming of the EOSS+*. For example, some of the systems are nearing retirement. (It is not known whether the EOSS+ will be able to test the FLIR 2000, which is under development for the HH-60 H/J helicopter, or what the FLIR 2000 test requirements are.) The 15 systems that are candidates for testing by the EOSS include the EO systems of the newer aircraft mentioned earlier.

Table 4. Ability of the EOSS+ to Test the Electro-Optical Systems of Navy and Marine Corps Aircraft

EO System	Description	Aircraft Platform	Number of Aircraft	Testability by EOSS+	Comments
AN/AAQ-16	FLIR	SH-2F	48	Not Fully Testable	Need platform stabilization
		MV/HV-22	475		
		Subtotal	**523**		
AN/AAR-37	IR Detection Set	P-3A/B/C	77	Not Applicable	Phased out
AN/AAR-40	IR Detection Set	P-3A/B/C	77	Not Applicable	Obsolete
AN/AAR-42	FLIR	A-7E	595	Not Applicable	Phased out
AN/AAR-47	Warning Set, Missile	CH-46D/E	442	Not Applicable	Spares cost less than TPS cost
		CH-53A/E	165		
		CH-53D	94		
		OV-10A/D	132		
		MV/HV-22	475		
		SH-2F	48		
		SH-60	122		
		UH-1n	213		
		Subtotal	**1691**		
AN/ARR-50	FLIR	F/A-18C/D	130	Yes	Concern for long run times
		F/A-18E/F	72		
		Subtotal	**202**		
AN/ARR-51	FLIR	AV-8B	63	Yes	TPS on contact
AN/AAS-33A	Laser Detection and Ranging Set	A-6E	104	Not Applicable	Being phased out
AN/AAS-36	IR Detection Set	P-3A/B/C	429	Not Fully Testable	Need platform stabilization
AN/AAS-37	IR Detecting Set	OV-10A/D	35	Not Applicable	Being phased out
AN/AAS-38A	Laser Target Designator/Ranger	F/A-18A/B	245	Not Fully Testable	Need platform stabilization and support equipment for OS and PFS WRA's
		F/A-18C/D	298		
		F/A-18E/F	72		
		Subtotal	**615**		
AN/AAS-42(XN-3)	IRST	F-14D	55	Yes	TPS on contract
AN/ALQ-144	IR Jammer	AH-IJ/5	115	Not Applicable	Will remain on current support equipment
		AH-1W	110		
		Subtotal	**225**		
AN/ALQ-144(v)	IR Counter Measures	OV-10A/D	35	Not Applicable	Will remain on current support equipment
AN/ALQ-144(v)2	IR Jamming System	SH-60B	122	Not Applicable	Will remain on current support equipment
		UH-1N	213		
		Subtotal	**335**		
AN/ALQ-144(v)3	IR Counter Measures	HH-60H/J	18	Not Applicable	Will remain on current support equipment
		OV-10A/D	115		
		SH-2F	48		
		Subtotal	**181**		

(Continued on the next page)

Table 4—*Continued*

EO System	Description	Aircraft Platform	Aircraft Number	Testability by EOSS+	Comments
AN/ALQ-157(V)	IR Counter Measures	CH-46D/E	174	Not Applicable	Will remain on current support equipment
		CH-53D	94		
		Subtotal	**268**		
AN/ASB-19(v)2	Angle Bomb Set	AV-8B	248	Not Fully Testable	Need platform stabilization
AN/ASQ-173	Laser Detector Tracker Strike Camera Pod	F/A-18A/B	245	Yes	
		F/A-18C/D	298		
		F/A-18E/F	72		
		Subtotal	**615**		
AN/AXQ-16(V)1	Cockpit TV Sensor	F-14A	510	Yes	
		F-14D	55		
		Subtotal	**565**		
AN/AXX-1	TV Camera Set	F-14A	510	Not Fully Testable	Need platform stabilization
		F-14D	55		
		Subtotal	**565**		
ATARS[4]	Adv. Tactical Airborne Rec. Sys.	F/A-18C/D	46	Yes	TPS written for CASS
		F/A-18E/F	72		
		Subtotal	**118**		
FLIR 2000	FLIR	HH-60H/J	32	Not known	
MX-10403/AXQ	TV Camera	F/A-18A/B	245	Yes	
		F/A-18C/D	298		
		F/A-18E/F	72		
		Subtotal	**615**		
MX-10987/AXQ	TV Camera	F/A-18C/D	130	Yes	
		F/A-18E/F	72		
		Subtotal	**202**		
MXU-810/U	Night Goggle Set	AV-8B	248	No	Requires means to test I/O
NTS4	Night Targeting System	AH-1W	110	Not Fully Testable	Need platform stabilization
OR-263/AA	FLIR	S-3A/B	264	Not Fully Testable	Need platform stabilization
		Subtotal	**264**		
RO-545/AXQ	Audiovisual Recorder	F-14A	112	Not Applicable	Can fault isolate without TPS
		F/A-18C/D	130		
		F/A-18E/F	72		
		Subtotal	**314**		
RO-570/AXQ	Audio Video Recorder[3]	F-14A	468	Not Applicable	Can fault isolate without TPS
		F-14D	55		
		F/A-18A/B	245		
		F/A-18C/D	298		
		F/A-18E/F	72		
		Subtotal	**1138**		
SVCR-120R-2A	Video Recorder	OV-10A/D	35	Not Applicable	Can fault isolate without TPS

Table 5. Testability of Systems

	Systems	Items
EO Systems Analyzed	31	9,491
Not Candidates for EOSS+		
Nearing retirement	5	888
Use spares, which are less costly than constructing TPSs	1	1,691
Use current support equipment; re-hosting to CASS is not planned	5	840
TPS is not needed	3	1,487
Testability is not known (FLIR 2000 for the HH-60H/J)	1	32
Not testable (MXU Night Goggles)	1	248
Total	16	5,186
Potential Candidates for EOSS+	15	4,305

2. Army Systems

This section presents two analyses of the ability of EOSS+ to test Army systems. The first, shown in Table 6, is a system-by-system analysis of 58 EO systems found on Army tanks and helicopters and listed in an Army EO Analysis [4]. The systems are described in the first and second columns of the table. The remaining columns describe the testability of these systems by the EOSS+. The third column lists those systems with which Northrop had experience, and which Northrop judged were fully testable by the EOSS+ [1]. The next three columns report our independent analysis to determine the testability of the *remaining* systems, the ones Northrop either did not analyze or did analyze and found not completely testable by the EOSS+. Our analysis, which is based on a comparison of EOSS+ capabilities listed in Reference [1] with Army EO requirements listed in Reference [4], indicates that seven of the systems have unknown EO requirements and nine of the systems operate outside of the frequency and power range of the EOSS+. This leaves 42 of the 58 systems that are either fully testable by the EOSS+ according to Northrop (11 systems) or at least in the right frequency and power range according to our own analysis (31 systems).

Table 6. Analysis of Army EO Systems

Platform or System	Number of Army EO Systems Analyzed	Number of EO Systems Northrop Listed as Fully Testable by EOSS+	IDA Analysis of Systems Not Listed by Northrop as Testable by EOSS+		
			Number of EO Systems Within EOSS+ Frequency and Power Range	Number of EO Systems Outside EOSS+ Frequency and Power Range	Number of EO Systems for which Testability is Unknown[1]
Abrams M1A2	6		5		1
Chaparral Missile System	3		1	2	
Dragon Missile System	6		5		1
Fire Support Team Vehicle (FISTV)	4	3	1		
HAWK Missile System	2	1		1	
Hellfire and Hellfire II Missile System	1		1		
JAVELIN Missile System	3		1	2	
Laser Target Designator	1		1		
Lightweight Airborne FLIR System	1		1		
Line of Sight Anti-Tank (LOSAT)	4		3	1	
OH-58D Helicopter	4	3			1
Modular Universal Laser Equipment (MULE)	2	1			1
Pedestal Mounted Stinger/Avenger	4		1	2	1
AH-64 Apache	7		5	1	1
Bradley Fighting Vehicle	3	2			1
TOW	4	1	3		
Unmanned Aerial Vehicle (UAV-SR)	3		3		
Total	58	11	31	9	7

[1] Equipment contains direct-view optics for which EOSS+ testability has not been established.

The second analysis is a sequential, three-step argument:

1. As we showed earlier, the EOSS+ is clearly superior to the EOSS.
2. A previous IDA analysis [5] found that the EOSS is more capable than all other testers, which, by implication, includes the Electro-Optical Augmentation (EOA) system developed by Pentastar.
3. An analysis by Redstone Arsenal [4] shows that the EOA could meet all the test requirements for the 58 Army systems listed in Table 6, except for the 3 systems of the Line-Of-Site Anti-Tank Vehicle (LOSAT) that use CO_2 lasers (discussed below).

The EOSS+ thus appears able to test a large number of Army systems. There are two areas of exception, however. The EOSS+ cannot test EO systems that employ either the CO_2 (10.6 μm) or the 1.54 μm lasers used in ranging and designator systems. Whether the EOSS+ should be modified to test these frequencies depends on the population of systems using these frequencies. The Army does not maintain a central source of frequency data, but our limited investigation indicates that some Army (and some Air

Force) systems do use these frequencies. Limited information on these two lasers is given in the next two paragraphs.

CO_2. The Army fielded its first CO_2 system several years ago. The system is incorporated in the Avenger laser rangefinder, which can be used in various platforms, including the Army's Avenger Line-of-Sight Rear (LOS-R) Air Defense System. Approximately 700 of these units were scheduled for delivery by the end of 1995. As of the spring of 1996, the only Army CO_2 system in development was the laser for the Line-of-Site (LOSAT) anti-tank weapon, which had passed Milestone I. A CO_2 laser was also planned for the M1A3 tank upgrade, but as of mid-1996, this program had been held up for lack of funding.

1.54 μm. The 1.54 μm laser is used in training situations as a substitute for the non-eye-safe 1.06 μm laser. This is a substantial usage, given that the Army uses the 1.06 μm laser in the rangefinders and designators for virtually all its land vehicles and helicopters. The 1.06 μm laser is also a part of the Army's MELIOS (Mini Eye-safe Lightweight Infrared Observation System) range-finder, which is used much as a pair of binoculars. Apart from its value in training, the 1.54 μm laser is being used in new Army laser rangefinders. The Air Force LANTIRN (Low Altitude Navigation and Targeting InfraRed) pod, which is installed on the F-15 and F-16 aircraft, uses both 1.06 μm and 1.54 μm frequencies on a switchable basis.

E. PROGRAM RISK

Our discussions with Northrop's program and engineering people uncovered several areas of concern. These are listed in Table 7, along with the recommendations we made for Navy consideration in April 1996. Some of the tests are not designed for the EOSS+, but because these tests will be required for EO systems now in development, the capabilities should be considered for incorporation as Pre-Planned Product Improvements (P^3Is) into the EOSS+. The remaining entries refer to capabilities that are being designed into the EOSS+ but which should be fully tested before EOSS+ production decisions are made.

Table 7. Program Risks and Recommendations

Problem Area	Recommendation
Inability to test CO_2 (10.6 μm) and 1.54 μm lasers	Consider for P^3I
Inability to test for scan linearity	Consider for P^3I
Method for testing arrays under vibration	
Scanning arrays	Test prior to production
Staring arrays	Test prior to production
Non-transfer of alignment method	Test prior to production
Integrated software package	Test prior to production
Test of integration of EOSS+ with hybrid CASS using a sophisticated new target system	Test prior to production

The remainder of this section discusses each of these problem areas.

Ability to test CO_2 and 1.54 μm lasers. As mentioned above, the EOSS+ cannot test these lasers, which are found in some fielded Army and Air Force systems, as well as in the LOSAT system under development. This capability should be considered for P^3I.

Ability to test for scan linearity. The EOSS+ cannot test for scan linearity. This is not a problem today because current forward looking infrared (FLIR) systems use costly electro-optical multiplexers that do not require precise scan linearity. Testing for scan linearity will be important in the future, however, because in the interest of saving money, second generation FLIRs and other IR sensors are being designed without these multiplexers. Scan nonlinearity in such systems will cause smeared images that degrade measurements of target range and resolution. Tanks can look like trucks or cars, for example. This capability should be considered for P^3I.

Ability to test arrays under vibration. Since all current IR sensors have scanning arrays, it is important to be able to test these arrays in the presence of vibration. Northrop developed a new method for doing this using signal-processing techniques, but the method should be fully tested before the production decision is made.

Almost all second-generation IR and TV sensors—those now under development—will use staring arrays. Northrop is developing a strobe method for testing these arrays under vibration; the strobe method should be tested before production.

Integrated Software Package. Most of the EOSS+ software package (the EOAMS, Electro-Optical Automation Measurement software package) is inherited from the fully tested EOSS software package, but 2,500 new lines of code are being added. Northrop says that the new code is not critical because it is used for housekeeping tasks,

rather than in test algorithms. Even if this is true, because the software is used for all tests, the completed software package should be tested prior to production.

Test of Integration of EOSS+ with hybrid CASS. It would be desirable to hold off full production of the EOSS+ until the Navy can test a full electro-optical CASS station consisting of a CASS hybrid integrated with an EOSS+ console. In May 1996, Northrop planned to test a hybrid CASS with an Automated Tactical Optical Support System (ATOSS), which is the electro-optical components of the EOSS+. However, a full EOSS+ (the ATOSS installed in a shell of the old EOSS, slightly modified) would not be available for testing until October 1996, when the two pre-production units were scheduled for completion. As an additional point, the full electro-optical station should be tested against a recent, more sophisticated system such as the F/A-18C/D/E/F FLIR.

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REFERENCES

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ABBREVIATIONS

ATOSS	Automated Tactical Optical Support System
BIT	Built-In-Test
CASS	Consolidated Automated Support System
EO	electro-optical
EOA	Electro-Optical Augmentation system
EOAMS	Electro-Optical Automation Measurement Software
EOSS+	Electro-Optic Subsystem
FISTV	Fire Support Team Vehicle
FLIR	forward looking infrared
IR	infrared
LANTIRN	Low Altitude Navigation and Targeting InfraRed
LOSA–T	Line-Of-Sight Anti-Tank Vehicle
LOS–R	Line-Of-Sight Rear
MELIOS	Mini Eye-safe Lightweight Infrared Observation System
MULE	Modular Universal Laser Equipment
O&M	Operations and Maintenance
OMB	Office of Management and Budget
P^3I	Pre-Planned Product Improvements

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13. ABSTRACT *(Maximum 200 words)*

This report documents research by the Institute for Defense Analyses on the cost and capabilities of the Electro-Optic Subsystem (EOSS+), the electro-optical module that the Northrop Grumman company is developing for the Navy's Consolidated Automated Support System (CASS). The research, which was completed in the spring of 1996, was sponsored by the Director, Weapon Support Improvement Group, Office of the Assistant Secretary of Defense (Economic Security) and conducted for the CASS Program Office, PMA-260 in the Naval Air Systems Command. We found that because of improvements in design, the EOSS+ is superior to the older EOSS in both total system cost and test capability. The EOSS+, moreover, will be able to test almost all electro-optical systems of recent Navy and Marine Corps aircraft and Army weapons. Based on these favorable findings, we recommended that the Navy continue developing the EOSS+, but test new design features (particularly, the newly developed software and methods for testing arrays) before production. The program office should also consider making Pre-Planned Product Improvements to enable the EOSS+ to test the newer CO_2 and 1.54 μm lasers.

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